Final Report

Technical and Economic Assessment of Biodiesel for Vehicular Fuel Use

presented to

The National SoyDiesel Development Board

1994

BOOZ·ALLEN & HAMILTON INC.

CONTENTS

SCOPE OF WORK

The objective of this report is to identify and analyze the technical and economic attributes of biodiesel—and to compare these attributes with those of other alternative fuels as well as with conventional diesel in on-road bus and truck fleets. The alternative fuels considered are compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), methanol and ethanol. The report contains an analysis of the operational, safety and emissions impacts of biodiesel relative to the other fuels. It also presents a life-cycle economic analysis comparing all the alternatives. Two fleet scenarios were considered: a medium-duty truck fleet (30 vehicles) and an urban bus fleet (200 vehicles). The report focuses on the on-highway market. Off-highway markets—such as marine vessels, locomotives and construction equipment—were not considered.

The economic figures, emissions data and physical properties used to assess the impacts of alternative fuels in this report have been obtained by Booz·Allen & Hamilton from a wide range of sources. These include government agencies, equipment and fuel suppliers, consultants and trade associations including the National SoyDiesel Development Board.

BIODIESEL FUEL OFFERS AN ALTERNATIVE TO "CLEAN" DIESEL FUEL.

- Processed from soybean oil—a renewable, biomass-derived feedstock, biodiesel readily mixes with standard diesel and can be used in blends at any proportion.
- Biodiesel can be substituted for diesel with essentially no engine modifications, particularly at lower blend levels.
- Biodiesel is biodegradable and contains about 11 percent oxygen by weight.
- Fuel properties differ from conventional diesel fuel. Biodiesel's zero sulfur and aromatic levels offer the potential for low emissions in diesel-cycle engines.

Average Properties of In-Use Fuels

	Standard Diesel No. 2	Federal Diesel No. 2	California Diesel No. 2	Biodiesel
Sulfur (wt %)	0.25%	0.03%	0.03%	~0.0%
Aromatics (vol %)	35% to 45%	35% to 40%	5% to 20%	~0.0%
Cetane Number[1]	~42	~42	~52[2]	~48

1. *Cetane tests are designed to measure the ignition performance of hydrocarbon fuels and may not properly reflect the ignition performance of oxygen-containing fuels like biodiesel.*
2. *There is a wide range of cetane values for California diesel currently on the market. When the California clean diesel regulations are fully phased-in at the end of the decade, the average cetane number should be in the mid to high 50's.*

LARGE VOLUME PRODUCTION OF BIODIESEL REQUIRES THE ADDITION OF ESTERIFICATION EQUIPMENT TO EXISTING OIL SEED CRUSHING AND REFINING FACILITIES.

- Biodiesel (a methyl ester) is produced by mixing refined, degummed soybean oil with methanol in an agitating reactor. Potassium hydroxide (KOH) or sodium hydroxide (NaOH) is used to catalyze the reaction.

- With current esterification processes, slightly more than 7 pounds of soybean oil are needed to make one gallon of biodiesel. About half a pound of crude glycerin is extracted as a co-product for every gallon of biodiesel. The extracted glycerin can be further refined to meet a 96 percent USP grade and therefore can be sold to the oleochemicals industry.

- Biodiesel can be manufactured by adding relatively inexpensive transesterification equipment to existing oil seed crushing and refining facilities. Oil seed crushers are currently operating at less than nominal capacity. Analysts conclude that soybean oil refining capacity is adequate to initiate a biodiesel market.

- At present, all of the biodiesel used in the U.S. is supplied to the market by Interchem Environmental, Inc. through a production arrangement with Procter & Gamble. Procter & Gamble has the capacity to supply up to 25 million gallons per year.

THE PRICE OF BIODIESEL PRICES DEPENDS GREATLY ON THE COST OF THE SOYBEAN OIL FEEDSTOCK.

- At the end of December 1993, biodiesel was being sold for $2.80 per gallon by Interchem Environmental. The price of the fuel varies significantly, depending on the cost of the soybean oil feedstock. In April 1993, biodiesel sold for $2.20 per gallon.

- Approximately 75 percent of final biodiesel product cost is due to the cost of soybean oil. The remaining 25 percent is attributable to processing, handling and capital plus a small profit margin. Because feedstock cost dominates the production economics, larger volume production will not have a large effect on biodiesel cost. Similarly, lowering processing costs will not greatly affect final product costs.

SOYBEAN OIL PRICES ARE IN A STATE OF FLUX.

- Due to crop damage and supply reductions caused by the Midwestern floods, soybean oil prices have climbed steadily since summer, 1993. Soybean oil prices have historically ranged between $0.20 and $0.22 per pound. At the end of December 1993, the price had increased to $0.30 per pound. (See facing page.)

- The cost of biodiesel may be reduced significantly by incorporating the use of other esters made from lower-cost feedstocks—for example, waste vegetable oil and tallow (animal fat).

- In this report, we will use low and high prices for biodiesel of $1.75 and $2.50 per gallon, respectively. $1.75 represents an optimistic near-term scenario and assumes that some lower cost feedstocks are used. The $2.50 value is representative of average prices over the past six to eight months.

On-Going Field Demonstrations ...

TRANSPORTATION DEMONSTRATIONS USING BIODIESEL ARE JUST BEGINNING ...

Southwest Ohio Regional Transit Authority, Cincinnati, OH	6 transit buses
Bi-State Development Agency, St. Louis, MO	50 vans, 250 planned
Lambert International Airport, St. Louis, MO	100+ ground vehicles
Greater Kansas Rapid Transit Authority. Kansas City, MO	4 transit buses, 250 planned
Denver Rapid Transit Authority, CO	2 transit buses
AC Transit, Oakland, CA	110 transit buses
Santa Cruz Harbor District, CA	2 heavy dredges and 2 harbor vessels
Sioux Falls, SD	16 transit buses
Yosemite National Park	4 tour buses
San Francisco MUNI, CA	100+ transit buses
Spokane Transit, WA	18 transit buses
Riverside, CA	10 school buses
City of Gardena Municipal Bus Lines, CA	1 transit bus

... and many others

... THE DEMONSTRATIONS HAVE FOCUSED ON A 20% TO 30% BLEND OF BIODIESEL FUEL WITH CONVENTIONAL PETROLEUM DIESEL.

DEMONSTRATION TESTING HAS BEEN VERY ENCOURAGING THUS FAR ...

- Use of biodiesel blends results in similar engine performance and no noticeable changes in fuel economy compared to standard diesel.

- No adverse durability or engine wear problems have yet been noted. However, additional high mileage demonstrations on biodiesel (multiple vehicles each accumulating over 100,000 miles) are needed to conclusively prove that there are no long-term durability impacts from using biodiesel.

- Maintenance requirements have not increased over those for diesel engines when using up to a 40 percent blend of biodiesel. At higher concentrations, more frequent oil changes may be recommended to prevent build-up of esters in the crankcase, thus diluting the engine oil.

- At 40 percent or higher blend levels, biodiesel will result in some deterioration of rubber and polyurethane foam materials. Any such materials coming in contact with the fuel should therefore be replaced with more resistant materials, which are available.

- Drivers have reported that a reduction in visible smoke emissions is readily apparent when using biodiesel. Visible smoke reductions appear to vary proportionally with the percentage of biodiesel in the fuel blend. Neat biodiesel results in essentially zero visible smoke.

... FLEET OPERATORS REPORT VERY FAVORABLE RESPONSES FROM DRIVERS AND THE PUBLIC TO THE USE OF BIODIESEL IN THEIR VEHICLES.

COMPETITIVE FUELS ASSESSMENT

BASIC FUEL PROPERTIES WILL DIFFERENTIATE THE ALTERNATIVE FUELS—AND INFLUENCE COMPETITIVENESS FOR VARIOUS TRANSPORTATION APPLICATIONS ...

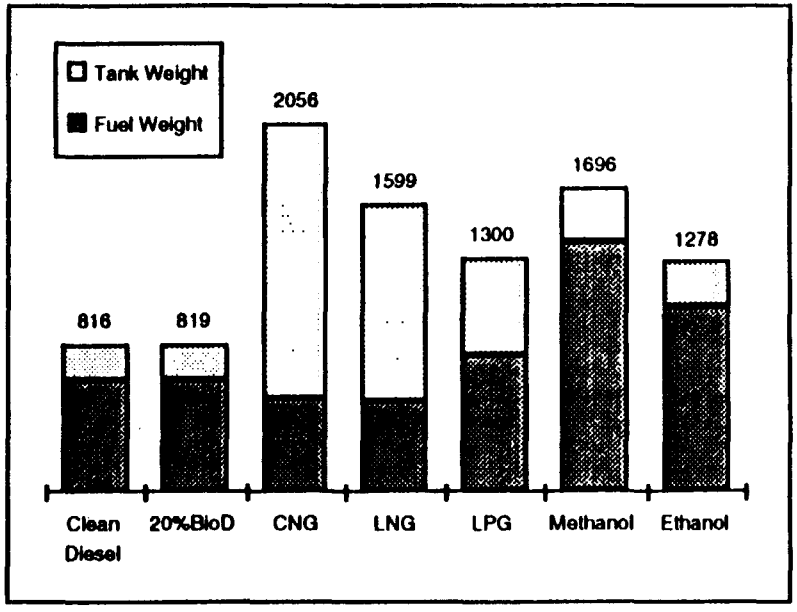
	Clean Diesel	100% Biodiesel	CNG	LNG	LPG	Methanol	Ethanol
Higher Heating Value							
- BTU/gallon	138,700	128,845	—	84,849	91,300	64,600	84,600
- BTU/lb	19,426	17,650	22,179	24,382	22,323	9,744	12,779
Lower Heating Value							
- BTU/gallon	128,700	120,188	—	76,425	83,500	56,560	75,670
- BTU/lb	18,025	16,464	20,200	21,961	20,416	8,531	11,431
Flash Point	175°F	300°F	(gas)	(gas)	(gas)	52°F	55°F
Flammability Limit							
- Upper	0.6%	n/a	5.0%	5.0%	2.5%	7.0%	4.3%
- Lower	5.5%	n/a	15.0%	15.0%	12.0%	36.0%	19.0%
Liquid Density (lbs/gal)	7.14	7.3	(gas)	3.48	4.09	6.63	6.62
Vapor or Gas Density Relative to Air	400% to 600%	n/a	60%	55%	153%	110%	159%
Relative Energy Density							
- By Volume	100.00%	93.39%	—	59.38%	64.88%	43.95%	58.80%
- By Weight	100.00%	91.34%	112.07%	121.84%	113.26%	47.33%	63.41%
Boiling Point at 1 Atm.	350°F to 720°F	600°F to 700°F	(gas)	-259°F	-44°F	149°F	172°F

n/a = specifications not available; however, biodiesel is regarded as having very low volatility.

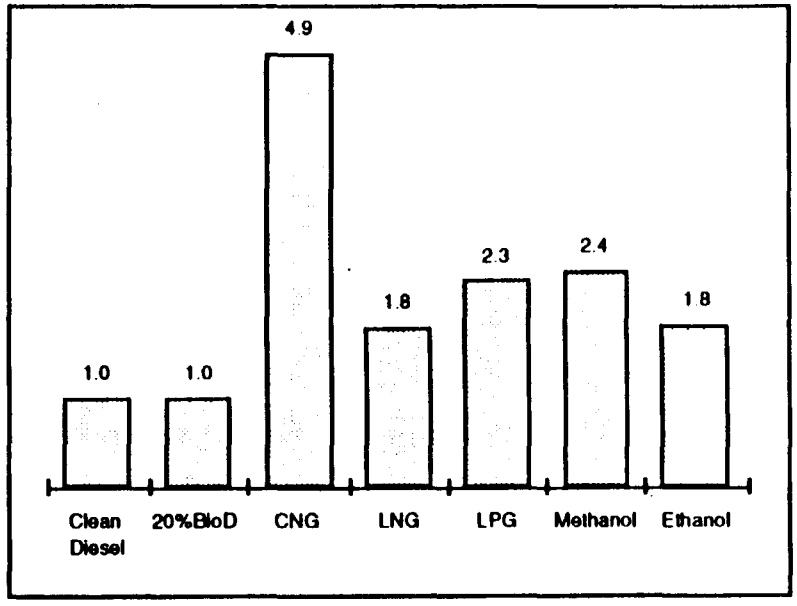
... THE PROPERTIES OF BIODIESEL ARE GENERALLY SIMILAR TO CONVENTIONAL DIESEL.

ON AN EQUIVALENT ENERGY BASIS, A 20% BIODIESEL BLEND OFFERS FUEL STORAGE ADVANTAGES COMPARED TO THE OTHER ALTERNATIVE FUELS.

FUEL SYSTEM STORAGE WEIGHT COMPARISON FOR 40' TRANSIT BUSES[1]



FUEL TANK VOLUME COMPARISON RELATIVE TO CLEAN DIESEL[1]



1. *See facing page for assumptions.*

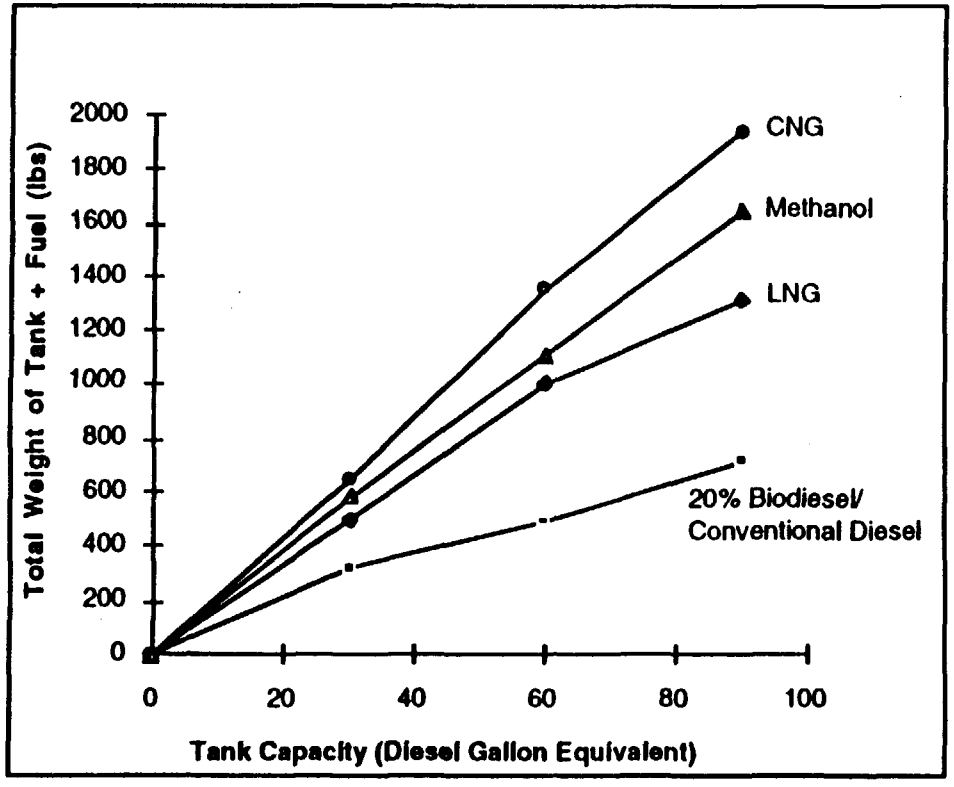
- Increased fuel system weight will reduce passenger-carrying capacity:

	Passenger Capacity Loss
Diesel/20% Biodiesel	0
CNG	8
LNG	5
LPG	3
Methanol	6
Ethanol	3

An average passenger is assumed to weigh 150 lbs.

BIODIESEL'S FUEL STORAGE WEIGHT AND VOLUME ADVANTAGES INCREASE WITH INCREASING FUEL STORAGE REQUIREMENTS ...

ON-BOARD FUEL SYSTEM STORAGE WEIGHT VERSUS CAPACITY



- A reduction in fuel storage weight and volume will
  - decrease brake and tire wear
  - improve fuel economy
  - increase payload capacity
  - maximize vehicle design flexibility

... LOW FUEL STORAGE WEIGHT AND VOLUME IS PARTICULARLY ADVANTAGEOUS FOR VEHICLES WITH HIGH FUEL CONSUMPTION RATES (LOW MPG) AND FOR APPLICATIONS HAVING HIGH DAILY MILEAGE ACCUMULATION (LONG VEHICLE RANGE).

BIODIESEL PRESENTS A REDUCED SAFETY HAZARD COMPARED WITH OTHER NON-PETROLEUM FUELS.

- Low pressure storage at ambient temperature
- Higher flash point
- Low vapor pressure
- Handles like diesel
- Non-toxic
- Biodegradable

BIODIESEL FUEL WILL REQUIRE NO MODIFICATIONS TO EITHER REFUELING STATIONS OR MAINTENANCE FACILITIES.

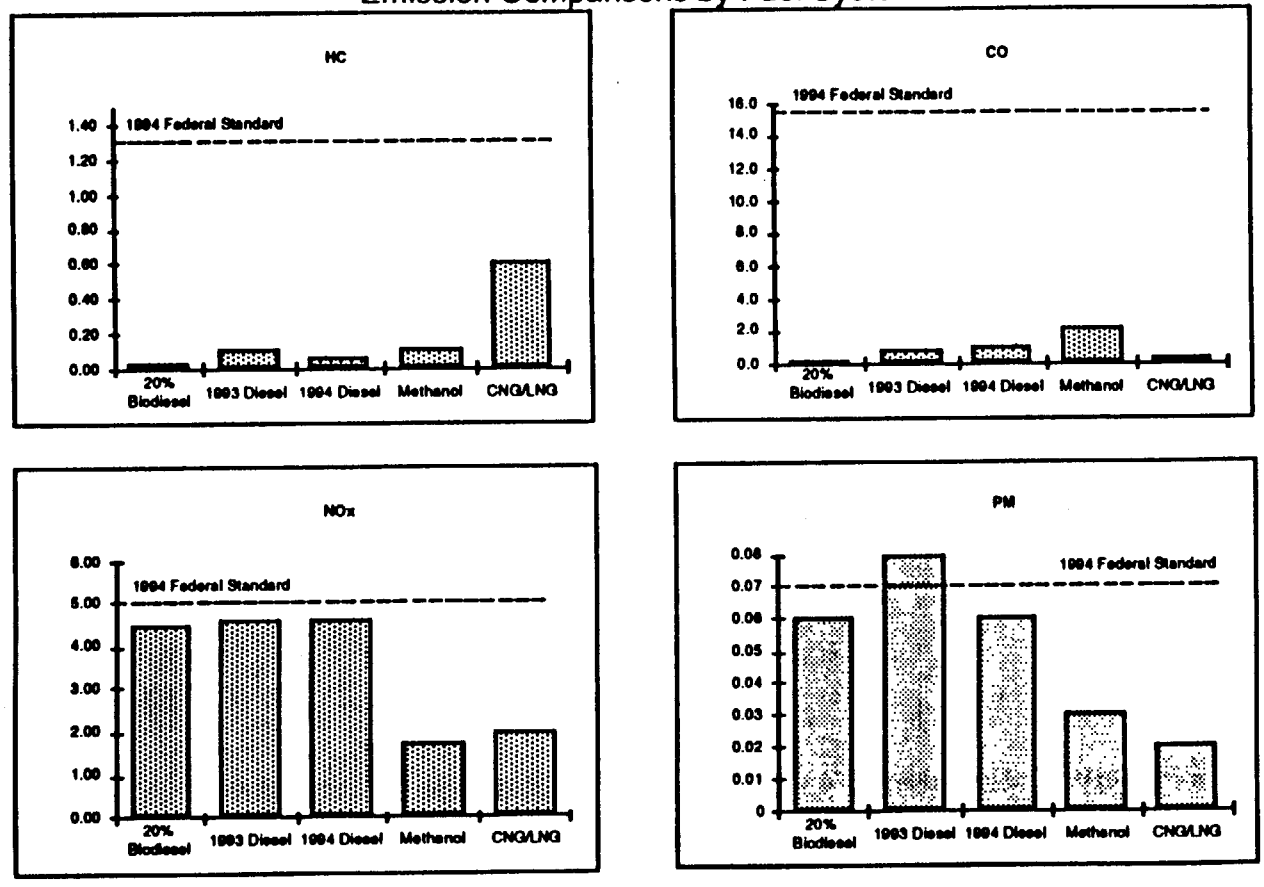
	20% Biodiesel	CNG	LNG	LPG	Methanol or Ethanol
Fuel Stations - Required Equipment	None	• Compressors • Gas conditioners • New fuel tanks • New dispensers • Safety equipment	• New fuel tanks • New dispensers • Safety equipment	• New fuel tanks • New dispensers • Safety equipment	• Alcohol-compatible fuel tanks • New dispensers • Larger fuel tanks • Safety equipment
Maintenance Facility - Required or Recommended Modifications	None	• Methane sensors • Electrical system upgrades • Increased ventilation • Fire suppression	• Methane sensors • Electrical system upgrades • Increased ventilation • Fire suppression	• Gas sensors • Electrical system upgrades • Increased ventilation • Fire suppression	• Electrical system upgrades • Increased ventilation • Fire suppression

BECAUSE BIODIESEL REQUIRES NO FACILITY MODIFICATIONS, THE FLEET CONVERSION PROCESS IS SIMPLIFIED.

- Permitting time and expense are eliminated.
- No transitional costs are involved—there is no need to fuel or maintain two fleets at the same time.
- Some fleet operations face facility space constraints—this is not an issue with biodiesel.
- No special personnel training is required.

DIESEL-CYCLE ENGINES HAVE INHERENTLY LOW HYDROCARBON (HC) AND CARBON MONOXIDE (CO) EMISSION LEVELS ...

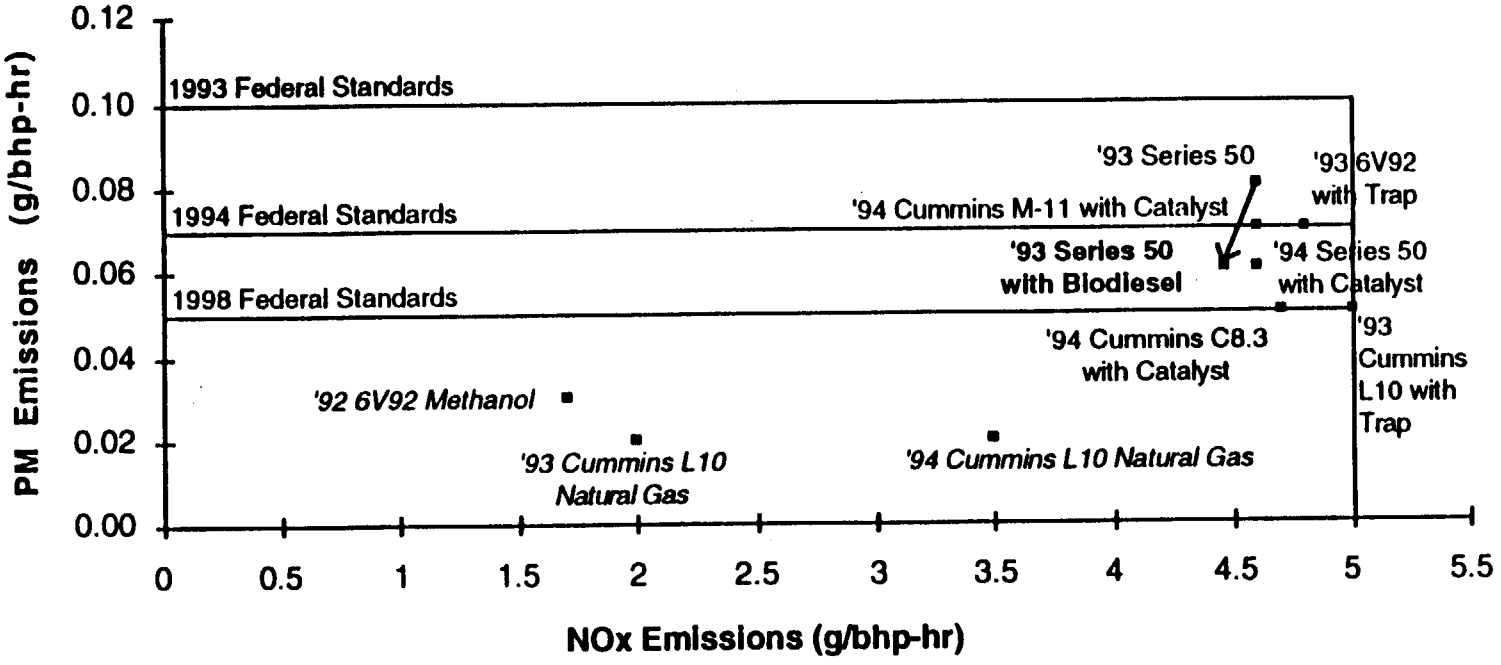
Emission Comparisons by Fuel System



Emission Data Used: Biodiesel: 1993 DDC Series 50; 1993 Diesel: 1993 DDC Series 50; 1994 Diesel: 1994 DDC Series 50; Methanol: 1992 DDC 6V-92TA; CNG/LNG: 1993 Cummins L-10 (see next page).

... THEREFORE, PARTICULATE MATTER (PM) AND NITROGEN OXIDES (NOx) ARE THE POLLUTANTS OF MOST CONCERN FROM HEAVY-DUTY ENGINES.

USING 20% BIODIESEL SHOULD REDUCE PM AND NOx EMISSIONS FROM BASE DIESEL ENGINES.



- However, 20% biodiesel cannot match the NOx and PM reductions of certified alternative fuel engines. Advanced diesel engines equipped with catalytic converters are able to achieve emission levels similar to those from biodiesel-powered engines. **More testing is needed to determine whether using biodiesel in an advanced diesel engine will result in additional incremental emission reductions.**

FLEET OPERATOR'S ECONOMICS

TO HELP GAIN AN UNDERSTANDING OF BIODIESEL AND ALTERNATIVE FUEL ECONOMICS, CAPITAL AND OPERATING COSTS HAVE BEEN DEVELOPED FOR TWO DIFFERENT TYPES OF FLEETS -- A MEDIUM-DUTY TRUCK FLEET AND A HEAVY-DUTY TRANSIT BUS FLEET ...

	MEDIUM-DUTY TRUCK FLEET	TRANSIT BUS FLEET
Baseline Fuel	Diesel	Diesel
Vehicle Type	Class 6 and 7 trucks	40-foot urban buses
Number of Vehicles in Fleet	30	200
Average Vehicle Service Life	5 years	12 years
Average Daily Range	85 miles	175 miles
Annual Mileage per Vehicle	25,000 miles	40,000 miles
Average Fuel Economy	8 mpg	3.8 mpg
Total Fuel Use per Day	320 gallons	8,750 gallons
On-Site Fuel Storage	12,000 gallons	60,000 gallons

... THE OPERATING STATISTICS LISTED ABOVE ARE TYPICAL FOR LARGER COMMERCIAL MEDIUM-DUTY TRUCK AND TRANSIT BUS FLEETS OPERATING IN THE UNITED STATES.

CAPITAL COSTS FOR FUELING FACILITIES WILL VARY CONSIDERABLY AMONG THE ALTERNATIVE FUELS ...

	DIESEL/ BIODIESEL	CNG	LNG	LPG	METHANOL/ ETHANOL
Medium-Duty Truck Fleet	0	$425,000	$300,000	$135,000	$100,000
Transit Bus Fleet	0	$2,000,000	$1,200,000	$550,000	$350,000

NOTES:

1) Biodiesel cost estimates assume that diesel storage tanks and fuel dispensers are already in place at the fleet operator's facility. A separate fuel storage tank and dispenser would be needed if biodiesel is not used throughout the fleet.
1) For the medium-duty truck fleet, on-site fuel storage of 12,000 gallons is assumed for the liquid fuels. This is the minimum size needed to accept a full load of fuel from a tanker truck.
2) For the transit bus fleet, on-site fuel storage of about 60,000 diesel-equivalent gallons is assumed for the liquid fuels. This amount of storage translates into a 7-day supply of fuel.
3) The CNG cost estimate for the medium-duty truck fleet is based on direct fast fill from storage. For the transit bus fleet, direct fast fill is assumed.
4) For both fleets, the LNG facility costs assume that LNG fuel is purchased from a vendor and stored on-site (i.e., no liquefaction plant is needed).

... AS NO FACILITY MODIFICATIONS ARE REQUIRED, BIODIESEL ENJOYS A CLEAR CAPITAL COST ADVANTAGE OVER THE OTHER ALTERNATIVE FUELS.

VEHICLE PRICES WILL BE HIGHER FOR THE ALTERNATIVE FUELS THAN FOR BIODIESEL.

	DIESEL/ BIODIESEL	CNG	LNG	LPG	METHANOL/ ETHANOL
Medium-Duty Truck[1]	$37,000	$46,000	$45,000	$42,000	$42,000
Transit Bus[2]	$210,000	$260,000	$255,000	$250,000	$230,000

1) Prices for alternative fuel medium-duty trucks are estimated based on the likely added cost of the on-board fuel storage system. The price given for the base diesel/biodiesel medium-duty truck is typical for a 26,000 lb GVWR delivery truck with a lift gate.

2) Prices for alternative fuel buses are based on recent successful bid prices for 40-foot buses in the transit industry.

NEW FUEL FORMULATION REQUIREMENTS HAVE RAISED THE COSTS OF DIESEL FUEL RELATIVE TO THE OTHER ALTERNATIVES.

DIESEL

- EPA regulations for low-sulfur diesel, which became effective on October 1, 1993, resulted in temporary increases in diesel fuel prices in many areas throughout the country. The wholesale, pre-tax price of diesel fuel has since stabilized at about $0.70 per gallon.

CNG

- For most fleet operators, the price of natural gas is set by the local utility and approved by the state public utilities commission. In some areas, natural gas used for vehicular purposes is partially subsidized by all ratepayers within the utility's service territory. Natural gas prices will, therefore, vary from region to region throughout the country. For the purpose of the economic analyses in this report, a natural gas price of $0.45 per therm (uncompressed) is used. This price is typical of utility rates for uninterruptible gas service.

LPG

- LPG sells for about $0.45 per gallon in bulk quantities (10,000+ gallons). The price of LPG fluctuates a great deal depending on seasonal and regional supply and demand.

TRANSIT OPERATORS ARE EXEMPT FROM MOST STATE AND FEDERAL TAXES ON MOTOR FUELS. COMMERCIAL FLEET OPERATORS ARE NOT ...

FEDERAL EXCISE TAX ON MOTOR FUELS

Diesel	20% Biodiesel	CNG	LNG	LPG	Methanol	Ethanol
$0.2440/gal	$0.2440/gal[1]	$0.4854/mscf ≈$0.05/dsl gal	$0.1830/gal	$0.1830/gal	$0.1140/gal	$0.1295/gal

1) Biodiesel is currently taxed at the same rate as conventional diesel. However, there is a proposal before Congress to provide up to a $0.85 per gallon tax incentive for biodiesel, equivalent on a energy basis to existing alcohol fuel incentives.

STATE TAX ON MOTOR FUELS
(Median Values of States with Established Taxes)

Diesel	20% Biodiesel	CNG	LNG	LPG	Methanol	Ethanol
$0.185/gal	$0.185/gal[1]	$.154/therm[2] ≈$0.17/dsl gal	$0.17/gal[3]	$0.17/gal[2]	$0.1875/gal	$0.1875/gal

1) Assumes that biodiesel is taxed at the same rate as conventional diesel (see note for previous table)
2) In many states, a flat annual fee is assessed in lieu of a tax on each fuel volume used.
3) An LNG fuel tax is not addressed by most state tax codes. Value in table assumes the same tax rate as LPG.

... CURRENT FUEL TAXES ARE NOT ASSESSED ON AN EQUIVALENT ENERGY CONTENT BASIS. THIS HAS THE EFFECT OF SKEWING FUEL COSTS IN FAVOR OF CNG ON A PER MILE BASIS.

BASED ON THE PREVIOUS FUEL PRICE ASSUMPTIONS AND INCLUDING TAXES FOR COMMERCIAL FLEETS, BIODIESEL'S EQUIVALENT FUEL COST PER GALLON IS COMPETITIVE WITH LNG AND LPG AND MUCH LOWER THAN THE ALCOHOL FUELS ...

	Clean Diesel	20% Bio-Diesel	CNG	LNG	LPG	Methanol	Ethanol
Wholesale Fuel Cost (Transit Fleet Price)	$0.70 per gal	$0.91 per gal	$0.68 per dsl gal	$0.55 per gal	$0.45 per gal	$0.60 per gal	$0.80[1] per gal
Wholesale Fuel Cost plus Taxes (MDT Fleet Price)	$1.13 per gal	$1.34 per gal	$0.90 per dsl gal	$0.90 per gal	$0.80 per gal	$0.90 per gal	$1.12 per gal
Fuel Cost per Mile							
• Transit Fleet[2]	$0.18	$0.24	$0.18	$0.24	$0.25	$0.38	$0.38
• Commercial MDT Fleet[3]	$0.14	$0.17	$0.11	$0.19	$0.21	$0.27	$0.25

1) *Assumes that ethanol is blended with 15 percent gasoline.*
2) *Assumes transit fleet obtains fuel economies shown previously in Fuel Storage Assumptions and Calculations Table, page 9-F.*
3) *Assumes a fuel economy of 8 miles per diesel-equivalent gallon. Medium-duty alternative fuel engines are assumed to have similar engine efficiencies as heavy-duty engines.*

... THE COSTS SHOWN ABOVE FOR 20% BIODIESEL ASSUME AN OPTIMISTIC FUEL PRICE OF $1.75 A GALLON FOR THE NEAT FUEL. IF NEAT BIODIESEL COSTS $2.50 A GALLON, THE EQUIVALENT FUEL COST PER MILE WOULD BE $0.28 AND $0.18 FOR THE TRANSIT AND COMMERCIAL MDT FLEETS, RESPECTIVELY.

THE TOTAL ANNUALIZED COSTS FOR THE VARIOUS ALTERNATIVES CAN BE COMPUTED FOR THE TWO TYPES OF FLEETS (MEDIUM-DUTY TRUCK AND TRANSIT BUSES) BASED ON THE PREVIOUS LISTED ASSUMPTIONS.

	Clean Diesel	20% Biodiesel $1.75	20% Biodiesel $2.50	CNG[4]	LNG	LPG	Methanol	Ethanol
Medium-Duty Truck Fleet								
• Incremental Fuel Costs	$0	$19,688	$25,706	($21,094)	$34,023	$53,083	$97,422	$77,719
• Cost of Compression	—	—	—	$5,786	—	—	—	—
• Incremental Fuel Facility Maintenance Costs	$0	$0	$0	$16,000	$5,000	$500	$500	$500
• Incremental Fuel Station Cost, Amortized[1]	$0	$0	$0	$62,400	$44,047	$19,821	$14,682	$14,682
• Incremental Annual Fleet Replacement Cost[2]	$0	$0	$0	$52,200	$46,400	$29,000	$29,000	$29,000
TOTAL ADDED COST	$0	$19,688	$25,706	$115,293	$129,470	$102,405	$141,604	$121,902
Transit Bus Fleet								
• Incremental Fuel Costs	$0	$442,105	$757,895	($33,684)	$439,359	$526,316	$1,564,290	$1,553,986
• Cost of Compression	—	—	—	$138,868	—	—	—	—
• Incremental Fuel Facility Maintenance Costs	$0	$0	$0	$78,000	$22,000	$1,000	$1,000	$1,000
• Incremental Fuel Station Cost, Amortized[3]	$0	$0	$0	$192,685	$115,611	$52,988	$33,720	$33,720
• Incremental Annual Fleet Replacement Cost	$0	$0	$0	$833,333	$750,000	$666,667	$333,333	$333,333
TOTAL ADDED COST	$0	$442,105	$757,895	$1,209,202	$1,326,970	$1,246,971	$1,932,344	$1,922,039

1) Amortized at 12% over 15 years.
2) 5 years service life, 20% salvage value assumed.
3) Amortized at 5% over 15 years.
4) Numbers in ( ) indicate a cost savings.

FOR FLEETS THAT MUST CONVERT TO AN ALTERNATIVE FUEL, BIODIESEL IS A COST-EFFECTIVE OPTION ...

- Compared to CNG (the leading alternative fuel candidate for medium-duty vehicles), biodiesel offers higher operating costs but substantially reduced capital costs—the total annualized cost for biodiesel is lower than any other alternative fuel option.

- The economic analysis considers direct fuel cost, fueling facility construction and maintenance cost, and vehicle replacement cost. There are also a number of one-time start-up costs associated with converting to alternative fuels, including maintenance facility modifications, personnel training, and parts inventory restocking. These costs can vary considerably for different fleet operators and thus were not included in this analysis. If all of these other costs are included, the annual cost differential between biodiesel and the other alternative fuels would be exacerbated.

- While less costly than converting to the other alternative fuels, using biodiesel will increase operating costs by 28 to 55 percent relative to low-sulfur diesel.

... HOWEVER, BIODIESEL IS NOT ECONOMICAL FOR FLEETS WHERE ALTERNATIVE FUEL CONVERSION IS NOT NECESSARY.

CONCLUSIONS

THE CHARACTERISTICS OF BIODIESEL FUEL MAKE IT AN ATTRACTIVE ALTERNATIVE FUEL FOR FLEET OPERATORS WHO REQUIRE A REDUCTION IN EMISSIONS ...

- Biodiesel is operationally very similar to clean diesel, requiring no changes in fueling station designs or on-board fuel systems.

- No degradations in performance or fuel economy have been observed from fleet operators using biodiesel blends.

- Biodiesel is as safe as or safer than diesel and the alternative fuels in storage and handling.

- Using biodiesel reduces visible smoke emissions — the primary public complaint of diesel trucks and buses.

- Because no additional capital or maintenance costs are incurred, the cost of converting to biodiesel is very competitive with converting to any of the alternative fuels. For the two fleet scenarios analyzed in this report, a truck or bus fleet using 20% biodiesel blended with conventional diesel would experience lower total annual costs than using LPG, CNG, LNG, ethanol or methanol.

... HOWEVER, BIODIESEL IS MORE EXPENSIVE THAN LOW-SULFUR DIESEL AND IS UNLIKELY TO ACHIEVE THE EMISSION REDUCTIONS OF THE OTHER ALTERNATIVE FUELS.

- Biodiesel blends can achieve incremental reductions in smoke, unburned hydrocarbons and particulate matter (PM). However, the reductions demonstrated thus far with biodiesel blends can also be achieved by newly developed, advanced diesel engines. NOx is the most difficult to control pollutant from diesel-cycle engines. If, as initial test results indicate, use of biodiesel blends results in higher engine-out NOx emissions, then original equipment manufacturers (OEMs) will likely not choose to certify a new engine on biodiesel fuel.

- Alternative fuel engines can achieve lower NOx (and PM) emissions than either diesel or biodiesel-fueled engines. As such, OEMs will continue to develop and market alternative fuel engines despite their higher associated costs.

- As it is unlikely to receive OEM support, biodiesel appears best suited as a PM and smoke reduction strategy for existing on-road vehicles.

- No regulations exist that would require the use of biodiesel (or any clean alternative fuel) in the existing fleet. **Without regulations to force its use or tax incentives to offset its costs, it is questionable whether any fleet operator would chose to use biodiesel as a substitute for low-sulfur diesel fuel.** Biodiesel is substantially more expensive than low-sulfur diesel, particularly at current prices of $2.50 or higher per gallon. At $2.50 a gallon for the neat fuel, a 20 percent biodiesel blend would increase per mile costs by more than 50 percent for a transit property.

AS AN ON-HIGHWAY FUEL, BIODIESEL'S APPEAL WILL BE LIMITED TO CERTAIN NICHE MARKETS.

- Many fleet properties are under pressure to reduce the emissions of their vehicles. In particular, transit fleets located in air quality nonattainment areas are often targeted for alternative fuels conversion. However, alternative fuel technologies are not yet fully mature, costs are high, and fuel infrastructures are not yet developed. Biodiesel may offer a lower-cost, short-term means for transit properties to achieve some emission reductions until a longer-term strategy can be implemented.

- Commercial fleet operators are not likely to embrace biodiesel in the absence of regulatory mandates or tax incentives. Keeping operating costs low is an important objective for most commercial fleet operations. The impact of using biodiesel on operating costs is minimized in intracity fleets with low overall fuel usage. For example, for the medium-duty truck fleet considered in our analysis (30 vehicles), the additional cost of using a biodiesel blend amounted to about $26,000 a year when biodiesel is $2.50 a gallon. For fleets in nonattainment areas, fleet rules or emission credit programs may be implemented which could incentivize commercial fleets to absorb the additional costs.

RECOMMENDATIONS

- For on-road applications, there is no guaranteed demand for biodiesel. The main problem with biodiesel for on-road vehicles is that its emission benefits are not great enough to justify its costs. **For biodiesel to have a chance of commanding a bigger share of the on-road fuels market, the NSDB should embark on a test program to develop a biodiesel-fueled engine that achieves PM and NOx reductions beyond those attainable from using low-sulfur diesel and catalytic converters in *new* engines, and/or low-sulfur diesel and standard rebuild kits in *existing* engines.** If such a program is successful, then biodiesel will benefit from regulations crafted to exploit its emission benefits.

- Biodiesel fuel may be an attractive fuel for certain off-road applications, particularly those applications where fuel usage is low and biodegradability becomes important. The California Air Resources Board has adopted or is contemplating the adoption of emission standards for marine vessels, utility engines and construction and farm equipment (under 175 horsepower). EPA is developing similar regulations to control emissions from off-road vehicles. Economic and operational issues of concern to off-road fleets often differ from those for on-road fleets. Biodiesel's inherent advantages would appear to be particularly attractive for off-road equipment operators. The off-road market is an area worthy of further exploration by the NSDB.